Space Technology Research Grants

MicroAngelo: 3D Nanostructure Fabrication by Manipulation of Surface Forces

Completed Technology Project (2013 - 2017)

Project Introduction

The goal of this proposal is to investigate a novel physical phenomenon and harness it for the creation of space devices. Spontaneous growth of microscale pillars and protrusions has been experimentally observed in heated, liquid nanofilms in confined geometries. These geometries consist of a heated bottom substrate, the molten film, an air gap and an upper substrate. There are three proposed theories to describe the underlying mechanism, but there is no clear consensus about the dominant physics. At the nanoscale, gravity becomes negligible and destabilizing surface forces, such as thermal or electric fields, can dominate surface tension to create structures. These fields cause stresses on the air-liquid interface and due to the small geometry, the liquid viscosity causes the bulk to respond to any deformation of the interface. Surface tension tries to repress small scale curvature in liquids and the films solidify almost instantaneously after the driving field is removed, so the structures are molecularly smooth. The first objective of this proposal is to understand the driving physics by comparing the spacing and growth rate of experimental observations to theory. Then, these instabilities will be optimized and harnessed as a technique to fabricate novel space microdevices. Because it sculpts and shapes the air-liquid interface at the microscale in a fundamentally different manner from traditional fabrication techniques, we call it MicroAngelo in reference to the famous Italian painter, Michelangelo. MicroAngelo rearranges the existing material into novel structures instead of adding or removing material in a noncontact, 3D, digitally controlled fabrication technique. Both experimental and computational techniques will be used in this project. The driving fields will be controlled electronically using feedback and the growth will be monitored by scanning white light interferometry. After growth, scanning electron and atomic force microscopy will be used for characterization. Due to the minute dimensions, direct measurement of the thermal or electric fields during the process is not feasible. Instead, finite element modeling will be used to model the relevant fields within the experimental apparatus. After determination of the driving mechanism, experimental focus will be turned to fabrication of space microstructures and numerical focus will emphasize the design. The application of emphasis for MicroAngelo is the creation of engineered materials and structures for space applications. Perhaps the most interesting possibility for this technique is the embedding and aligning of nanostructures. These structures can be aligned by the liquid flow to enhance various properties of the film. Carbon nanotubes embedded in lightweight polymeric films can create strongly anisotropic thermal conductivities favoring the alignment direction of the carbon nanotubes. Additionally, nanotubes change the ballistic toughness of the bulk material to make a surface more damage tolerant. Beyond this, the surface geometry could be engineered to be an array of high aspect ratio nanorods coating a solar cell. These nanorods are a strongly absorbing surface that can surpass the thermodynamic limit of absorption for an unstructured film of equal mass. By absorbing more light on the surface, a greater portion of the energy can be converted into current by the solar cell.

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Anticipated Benefits

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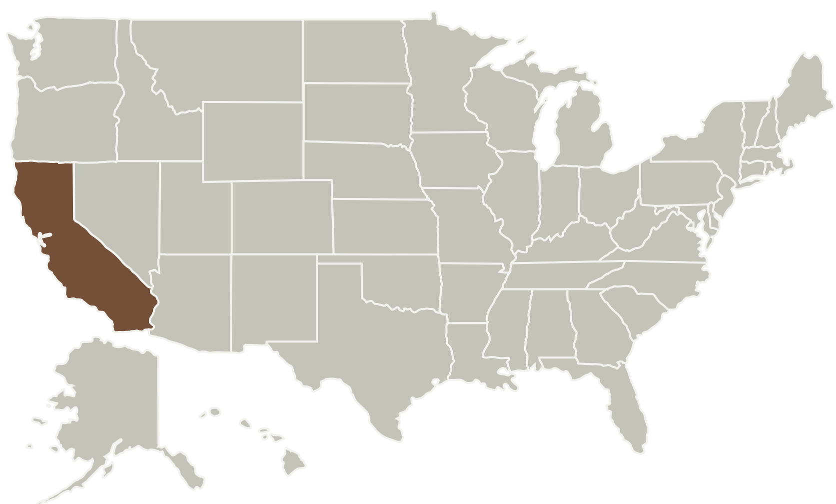
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
California Institute of Technology(CalTech)	Lead Organization	Academia	Pasadena, California

Primary U.S. Work Locations
California

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

California Institute of Technology (CalTech)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Sandra M Troian

Co-Investigator:

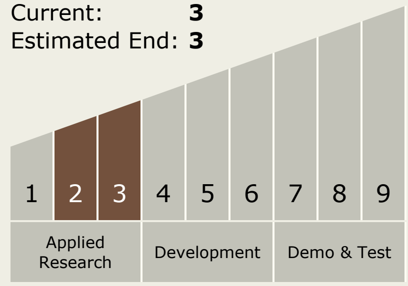
Kevin R Fiedler

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX10 Autonomous Systems
  - └ TX10.3 Collaboration and Interaction
    - └ TX10.3.4 Operational Trust Building

Target Destination

Foundational Knowledge